# NACA

# RESEARCH MEMORANDUM

INVESTIGATION OF THE EJECTION RELEASE OF SEVERAL

DYNAMICALLY SCALED BLUFF INTERNAL STORES AT MACH

NUMBERS OF 0.8, 1.39, AND 1.98

By Howard S. Carter and John B. Lee

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# NATIONAL ADVISORY COMMITTEE
# FOR AERONAUTICS

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## SUMMARY

An investigation was conducted in a free jet to determine the flight behavior after ejection from a bomb bay of several dynamically scaled bluff internal stores. The tests were made at Mach numbers of 0.8 and 1.39 for simulated altitudes of 3,400 and 4,000 feet and at a Mach number of 1.98 for a simulated altitude of 35,000 feet. The Reynolds numbers varied from $6 \times 10^6$ to $14 \times 10^6$.

The trajectories for all store releases were smooth and at no time after release did any store come close to striking the fuselage from which it was ejected. However, the disturbed flow field in the close vicinity of the bomb bay had strong influences on the pitching motions of the stores; this caused some stores to pitch to angles as high as $30^\circ$. Several minor variations were made in the test conditions and in the external shape of the stores in an attempt to reduce the magnitude of the pitching. These variations made no significant reduction in the magnitude of the pitching oscillations except for the flared-cylinder store. The pitching oscillations of this flared-cylinder store were much better damped than for any other configuration tested when this store was ejected without a plate in front.

## INTRODUCTION

Very few problems are encountered in the release of internal stores from airplanes if the pressure forces on the stores are small in comparison with the gravity forces. However, at high subsonic speeds, the pressure forces on lightweight stores were of the same order of magnitude as the gravity forces and caused tumbling and erratic initial trajectories (ref. 1). At supersonic speeds, the pressure forces can be greater

in magnitude than the gravity forces and, hence, the release of internal stores has presented an increasingly difficult problem. If the store and bomb bay are not properly designed and if proper release methods and techniques are not used, the store may be damaged due to aerodynamic overloading, or the path of the released store at supersonic speeds may be such as to intercept the airplane which released it. Also, it is desired that store oscillations be minimized in order to obtain accurate trajectories. In addition, at supersonic speeds, interference effects may also have a large influence on stores in the vicinity of the airplane.

Some work has been done at supersonic speeds on streamlined internal stores (for example, refs. 2 and 3). Reference 3 also includes some supersonic ejection data on a bluff internal store. Reference 4 concerns some tests of a bluff store at low subsonic speeds. In these tests, it was shown that a dynamic stabilizing plate in front of the store as tested eliminated the continuous oscillations. The purpose of this investigation is to test the ejection release of this configuration and other bluff stores at high speeds. These tests were made in the preflight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The stores were ejected downward at a velocity of 20 and 30 feet per second from a fuselage which simulated a current fighter-bomber configuration. This fuselage was mounted at the exit of the 27-by 27-inch nozzles. The tests were performed at sea-level conditions at Reynolds numbers per foot of $6 \times 10^6$, $10 \times 10^6$, and $14 \times 10^6$ for Mach numbers 0.8, 1.39, and 1.98, respectively.

## SYMBOLS

| | |
|---|---|
| $d$ | store diameter, in. |
| $h_p$ | simulated pressure altitude, ft |
| $I_y$ | inertia about the center of gravity, slug-in.$^2$ |
| $i_o$ | preset store incidence angle, deg |
| $l$ | store length, in. |
| $m$ | mass, slugs |
| $M_\infty$ | free-stream Mach number |
| $p$ | pressure, lb/in.$^2$ |
| $t$ | time, milliseconds |

W            store weight, lb

x            horizontal distance, positive downstream, in.

z            vertical distance, positive downward, in.

$\dot{z}_0$            ejection velocity, ft/sec

$\alpha_f$            angle of attack of fuselage with free-stream direction, deg

$\theta_s$            store pitch angle referenced to horizontal, deg

Subscripts:

m            model

p            prototype


## MODELS AND APPARATUS


### Stores

Drawings and photographs of the bluff stores released in these tests are shown in figures 1, 2, and 3 for the Wright Air Development center (WADC), flared-cylinder (FC), and cylindrical (C) stores, respectively. Additional description of the stores is given in table I. Because of the large variation in weights and inertias needed for the stores, they could not all be constructed of the same material. The basic bodies of the stores were made of either balsa, mahogany, or magnesium. The circular plates at the front were made of either aluminum, magnesium, or steel and the spacers behind the plates were made of aluminum. The cores, which were placed in the stores to give the needed center-of-gravity locations, weights, and inertias, were made of either lead or tungsten. The design and construction techniques used yielded weights and inertias within ±10 percent of the desired values.


### Fuselage and Bomb Bay

A 1/17-scale model of the lower half of the fuselage of a current fighter-bomber configuration was used for these tests. A photograph of the one-half fuselage mounted in the preflight jet is shown in figure 4. The model fuselage was a semicircular cylinder with a streamlined nose. The fuselage was mounted to an extension of the nozzle upper plate with the front end of the bomb bay coinciding with the nozzle exit plane.

The inside walls of the bomb bay were shaped to the contour of some streamlined stores which were also released from this same configuration. The only alterations to the bomb bay were slight cutouts from the inside ceiling to allow the bluff stores to be fully retracted into the bomb bay.

A sketch of the fuselage showing the ejection cylinder and a typical store in retracted and in release positions is presented in figure 5. The store in retracted position was completely inside the bomb bay. At release, the store was 1.77 inches below the retracted position and was completely outside the bomb bay. The ejection cylinder shown on top of the fuselage is described fully in reference 3.

## Preflight Jet and Test Equipment

A photograph of the test equipment and its arrangement in the pre-flight jet of the Langley Pilotless Aircraft Research Station at Wallops Island, Va., is presented in figure 6. A description of the preflight jet (free jet) is given in reference 5. The model shown in this photograph was a streamline store previously tested and is not discussed herein, but the arrangement of the test equipment was identical for these tests.

An 8 by 10 camera mounted in position to photograph the store positions as seen from the side is shown. Mounted below the jet is another 8 by 10 camera to photograph the store positions as seen from that point. A bank of 20 Strobolights can be seen mounted in a position to illuminate the released store in a manner suitable for photography from both the side and bottom cameras.

A shadowgraph of the flow field at $M = 1.39$ in the close vicinity of the bomb bay is presented in figure 7. An ejector (incidence angle of $-6°$) is shown extended to its maximum downward position which is the position for store release. Shock waves can be seen emanating from both this ejector and other sources.

## TESTS

### Dynamic Similarity

For dynamic testing, exact simulation of prototype conditions is desirable. The usual procedure, however, is to match the similarity parameters that have the greatest influence on test data. Corrections may then be attempted to account for the effect of those parameters which are not duplicated, or if it can be shown that the probable differences are small, they may be neglected.

The Mach numbers for the model tests were the same as for the air-
plane. The effect of not testing at full-scale Reynolds number was
assumed to be negligible. Dynamic scaling was obtained by: (1) main-
taining the ratio of store density to dynamic pressure the same for the
model as for the prototype store and (2) maintaining the mass distribu-
tion of the store model the same as that in the store prototype. This
scaling results in the following scaling equations:

$$\left(\frac{p l^5}{I}\right)_m = \left(\frac{p l^5}{I}\right)_p \tag{1}$$

and

$$\left(\frac{p l^3}{m}\right)_m = \left(\frac{p l^3}{m}\right)_p \tag{2}$$

The basis for this similarity is enlarged upon in references 3 and 6.

Since the acceleration due to gravity cannot be altered, the verti-
cal acceleration due to gravity for the model tests is too small for
dynamic similarity by the scale factor. The effect of not properly sim-
ulating gravity has been shown in reference 6. Since these tests are
made with ejection velocities of 20 or 30 feet per second, the effect of
gravity on the vertical displacement of the model is within 15 and 10 per-
cent, respectively, of full-scale values. Hence, except as affected by
a vertical-position error as noted, all aerodynamic forces, moments, the
resulting pitching angles, vertical and horizontal displacements due to
aerodynamic forces, and all damping effects are faithfully represented.

Test Methods

The temperature and pressure of the flow at the exit of the 27- by
27-inch nozzle were maintained at sea-level conditions throughout the
testing time. At the beginning of each test, an electrical impulse
actuated both the ejection mechanism and the photographic equipment.
The ejection cylinder, which had been pressurized to give the desired
velocity at the end of the stroke, propelled the store downward. The
shutters of the 8 by 10 cameras, which were set to stay open for 50 milli-
seconds, allowed stroboflash pictures to be made at 2- or 3-millisecond
intervals starting before release and continuing for 40 or 50 milliseconds
The picture obtained is thus a composite Strobolight picture of a scaled
time trajectory on one sheet of 8 by 10 film. The store pitch angle and
trajectory were read directly from this Strobolight picture.

## RESULTS AND DISCUSSION

The purpose of this investigation was to determine the flight char-
acteristics in the vicinity of the airplane of several proposed bluff-
store configurations.  Table I lists the tests and pertinent data of each
test.  Figures 8, 9, and 10 are Strobolight pictures of tests for the
WADC, flared cylinder, and cylindrical stores, respectively.  The vari-
ables which were investigated during the release of these stores were
fineness ratio, center-of-gravity location, external stabilizing devices,
initial release velocity, angle of attack of fuselage, and combinations
of dynamic pressure and Mach number.  The effect of these variables can-
not be determined by observing the Strobolight pictures alone.  Hence,
the data obtained from the Strobolight pictures (pitch angle and trajec-
tory data) are plotted for comparison of the effect of the variables in
figures 11 to 19.  In these figures, only the necessary statistics which
are needed for comparison are given.  The data which are not listed in
the figure legends were omitted since they were similar for all tests
presented in the figure.

Zero time on all the curves in this report is the instant of release
of the store from the ejection mechanism.  The data obtained prior to
this time are not presented, although they were used in the fairing of
the curves near zero time.

Before the ejection mechanism was energized, the incidence angle
between the fuselage and the store was zero.  However, after the mech-
anism was energized and the store started to emerge from the bomb bay,
the drag of the store caused the ejection shaft to bend and hence, the
incidence angle became negative.  The amount of bending varied with each
test and, hence, could not be compensated for in prior adjustments.  The
data figures, for tests where the fuselage was at zero angle of attack,
show this variation in incidence angle at zero time.  This variation in
incidence angle seemed to have little or no effect on the flight charac-
teristics after the first few milliseconds.

It is apparent from the Strobolight pictures and from the trajectory
curves that each store release was successful in that each store had a
satisfactory trajectory.  These bluff-store trajectories were a decided
improvement over the fineness-ratio-6.0, streamlined store trajectory
(similarly tested) which is shown in reference 6.  The bluff stores had
smooth trajectories and at no time after release did any of them come
close to striking the fuselage from which they were ejected.  However,
from the standpoint of stability, it appears that the released stores
were poorly damped.  The magnitude of the pitching increased with time
and it could not be determined from these tests whether or not the
released stores would continue to increase in pitch amplitude until they
diverged.  Unpublished data show that the oscillations of a cylinder

model (center of gravity at 30 percent) similar to store C-5 (center of gravity at 35 percent) were dynamically damped in relatively undisturbed flow at supersonic speeds.

Another factor to be considered is the influence of the flow field in the vicinity of the airplane. (See fig. 7.) Such phenomena as shock waves, pressure gradients, and unknown flow components may have strong influences on the pitching motions of the stores. Reference 2 shows that some streamlined internal stores encountered violent variations in angle of attack in the vicinity of the airplane when released into flow which had high dynamic pressures. These streamlined stores were simple bomb shapes which could be expected to be well damped in relatively undisturbed flow for the same free-stream conditions. It is possible also that these bluff-type stores may be poorly damped in the disturbed flow field in the close vicinity of the airplane but well damped in an undisturbed flow field. A shadowgraph negative of the flow field was superimposed over the Strobolight pictures in an attempt to visually delve into this problem of shock-wave interferences. No definite conclusions could be made from this method concerning the oscillations of the stores.

As shown in figures 4 and 6, the model fuselage was a simulation of the lower half of the fuselage of a current fighter-bomber configuration, was attached to a flat plate, and did not have a wing. It has been shown by unpublished data that there is enough influence of a wing on the flow field in the close vicinity of the fuselage to affect noticeably the oscillations and trajectories of stores falling through the flow field.

The oscillations of the stores after release were considered undesirable from the standpoint of the acceleration forces and the aerodynamic loads imposed on the stores. Hence, several geometric alterations were made to the original stores in an attempt to reduce these pitch forces and amplitudes. Also the simulated altitude and tunnel release conditions were varied for this same purpose. The tests will be discussed in light of these variations and comparisons will be made to try to show the results of these variations on the flight characteristics of the stores.

## WADC Stores

Variation in angle of attack of fuselage.- Figures 11(a) and 11(b) show the curves for some WADC store releases in which there was a variation of $3^\circ$ in angle of attack of the fuselage. No appreciable effect was indicated either on the frequency or magnitude of the pitch oscillations nor on the trajectory by this variation of $3^\circ$ in fuselage angle of attack. At M = 1.98, the increase of fuselage angle of attack appears to have caused a timewise shift in the oscillations. However, this same shift is noted later in other tests where there was no variation in fuselage angle of attack. The data in this report indicate that the flight

characteristics of the bluff stores are relatively insensitive in the
vicinity of the airplane to small variations in fuselage angle of attack.

Variations in external shape.- Several tests were made at  M = 1.39,
1.98, and 0.8 to determine what the effect would be on the pitching
motions and trajectories of the WADC stores if the external shapes were
varied.  Each of the shapes tested had been proposed as shapes that might
reduce the magnitude of the pitch oscillations.  Reference 4 states that
the purpose of adding plates to the front of these WADC stores was to
provide a compensating channel between the upper and lower surfaces of
the store to allow the pressures to equilibrate.  Thus, in theory, the
store would be better damped.  By referring to figure 12 and to table I,
a full description of each store and the variations between stores can be
obtained.

The trajectories for each Mach number were the same and showed no
variation due to these geometrical changes.  The pitch-angle—time curves
are all slightly different on each figure.  However, there seems to be
little or no correlation between these differences in the data curves
and in the geometrical differences in the stores.  For example, the
changes such as nose plate, radius on nose, truncated cone, or stabilizing
fences seemed to make no significant differences in the flight character-
istics of the stores in the close vicinity of the airplane.  A small
decrease in maximum pitch amplitude was noted at  M = 1.39  with the use
of a plate but no decrease at  M = 1.98.  The use of stabilizing fins
gave the shortest pitch period and the truncated cone afterbody, the
longest.  The changes made in these tests were intended to help damp the
store oscillations and still maintain a nearly cylindrical shape.

Variations in initial release velocity.- In order to determine the
effect of initial vertical release velocity, store WADC-6 was released
at velocities of 30 and 20 feet per second.  Figure 13 presents the
results of these two tests.  The pitching amplitude was slightly less
for the higher release velocity.  No definite conclusions can be made
because of this difference; however, the higher velocity did make a
noticeable increase in the distance dropped.

Repeatability.- The data presented for the WADC stores had varia-
tions in initial pitch angles and pitch amplitudes which could not be
explained.  Tests were made for repeatability using two WADC-3 stores.
The results of these tests are shown in figure 14.  Some scatter is
evident, but for all practical purposes the repeatability was good.

## Flared-Cylinder Stores

Variations in external shape.- Two tests were made at  M = 1.39
and two at  M = 1.98  to determine what the effect would be on the flight
characteristics of the flared-cylinder stores if the external shapes were
varied.  The effect of adding a plate in front of a flared-cylinder store
at  M = 1.39  is shown in figure 15(a).  The trajectories were almost
identical for the duration of the tests; however, the oscillations of
the two stores were considerably different.  The addition of the plate
caused a decided increase in pitch amplitudes.

The variation in the flight characteristics at  M = 1.98  of a
flared-cylinder store with one large plate and with two plates is shown
in figure 15(b).  The addition of a second plate caused a slight varia-
tion in pitching motions, but not to the extent that could be considered
an improvement over the store with one large plate.

## Cylindrical Stores

Variations in fineness ratio.- In an attempt to determine the effect
of fineness ratio on the flight characteristics of the cylindrical stores,
several tests were made at  M = 1.39.  Figure 16 presents the curves for
two stores with fineness ratios of 1.55 and 2.03, respectively, and fig-
ure 17 presents the curves for two stores with fineness ratios of 2.54
and for two stores with fineness ratios of 3.04.  For all these tests,
the inertias and weights for the stores and the initial pitch angles
were somewhat different.  Furthermore it appeared, in this close vicinity
of the airplane, that the stores were poorly damped.

Reference 7 presents data which enable estimates to be made of the
center of pressure of circular cylinders.  By using the curves given in
this reference, the center of pressure of the cylindrical stores was
estimated for  M = 1.39.  The cylindrical stores having fineness ratios
of 1.55 and 2.03 (fig. 16), were estimated to be statically stable;
when tested, the oscillations of these stores were regular.  The cylindri-
cal stores having fineness ratios of 2.54 and 3.04 (fig. 17), were esti-
mated to be marginally stable; when tested, the oscillations of these
stores were erratic.

The pitching oscillations of the stores did not cause any erratic
movements in the trajectories.  Figure 17 indicates, however, that the
trajectories were influenced to some degree by the average of these
pitching angles.  A more positive average angle caused lift on the store
and hence tended to hold it up; whereas, a more negative average angle
caused a down force on the store and hence tended to push it down.

Variations in center of gravity.- The effect of changing the position of the center of gravity was attempted in the tests for which data are shown in figure 17. Because of the erratic oscillations of the stores, no definite conclusions can be made concerning this effect of a shift in the center of gravity.

Variation in dynamic pressure and Mach number.- Store C-4 was released at 35,000 feet simulated altitude for Mach numbers of 1.39 and 1.98. The Mach number was varied by a factor of about 1.42 and the dynamic pressure was varied by a factor of about 2. Since two parameters, which may have affected the release, were varied, no definite conclusions can be made as to the effect of either. However, it appears from figure 18 that a combination increase in Mach number and dynamic pressure caused an increase in pitch amplitude.

## Comparison of the Three Configurations

In order to compare the release characterisitics of the three bluff-type configurations, a pitch oscillation and trajectory curve for one of each type is plotted against time in figure 19. The stores chosen for this comparison were the ones which exhibited the best release characteristics for their respective group. The three stores were very nearly alike in fineness ratio and center-of-gravity location and the test conditions were identical. Hence, the differences in the data curves must be due mainly to the differences in external shape.

The trajectory curves were very similar throughout the time covered by these tests. Apparently, the pitching motions of the stores and the differences in external shape that existed had small influence on the lift and drag of the stores. This small influence of the pitching motions on the trajectories seems to have been true for all tests reported herein.

It is apparent from figure 19 that the flared cylinder (without a plate in front) was much better damped during the time interval of these tests than either the WADC or the cylindrical stores. Also the WADC and cylindrical stores were similar in behavior in the close vicinity of the fuselage, and it appears that the refinements made in the WADC stores did not make them superior to the simple cylindrical stores.

## CONCLUSIONS

An experimental investigation was conducted in a free jet to determine the ejection release characteristics and flight behavior in the close vicinity of the fuselage of several bluff-type internal stores

which were ejected from the bomb bay.  The tests were made at Mach numbers of 0.8 and 1.39 for simulated altitudes of 3,400 and 4,000 feet and at a Mach number of 1.98 for a simulated altitude of 35,000 feet.  The Reynolds numbers varied from $6 \times 10^6$ to $14 \times 10^6$.  It may be concluded from these tests that in the close vicinity of the fuselage:

1. The stores had smooth trajectories and, although in some releases they pitched as high as 30°, at no time after release did any of them come close to striking the fuselage.

2. Geometrical changes to the WADC stores such as the addition of a nose plate, the addition of stabilizing fences, change to radius on nose back of plate, and a change to a truncated cone afterbody made no significant differences in the flight behavior of the stores.

3. The flared cylinder without a plate in front was much better damped at Mach number 1.39 than the same flared cylinder with a plate in front.  It was also much better damped than any of the WADC or cylindrical stores.

4. The WADC and cylindrical stores were similar in behavior, and it appears that the refinements made in the WADC stores did not make them superior to the simple cylindrical stores.

5. A test for repeatability indicated that the oscillations and trajectories could be closely repeated if all conditions for testing were the same.


Langley Aeronautical Laboratory,
         National Advisory Committee for Aeronautics,
                  Langley Field, Va., August 9, 1956.

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TABLE I.- SUMMARY OF PRETEST DATA

| Test | Figure | Store | Model description | | | | | | | | | Tunnel conditions | | Release conditions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Center-of-gravity station in - | | | | | | | |
| | | | Remarks | $l$, in. | d, in. | $l/d$ | W, lb | $I_{yg}$, lb-in.$^2$ | in. | percent | $M_\infty$ | $h_p$, ft | $\dot{z}_o$, ft/sec | $\alpha_f$, deg | $i_o$, deg |
| 1 | 8(a) | WADC-1 | No plate | 4.62 | 1.794 | 2.58 | 0.407 | 0.430 | 1.60 | 34.6 | 1.39 | 3,400 | 30 | 0 | 0 |
| 2 | 8(b) | WADC-1 | No plate | 4.62 | 1.794 | 2.58 | .407 | .435 | 1.60 | 34.6 | 1.39 | 3,400 | 30 | 3 | 0 |
| 3 | 8(c) | WADC-3 | WADC-1 plus plate | 4.62 | 1.794 | 2.58 | .405 | .615 | 1.62 | 35.1 | 1.39 | 4,000 | 30 | 0 | 0 |
| 4 | 8(d) | WADC-3 | WADC-1 plus plate | 4.62 | 1.794 | 2.58 | .449 | .496 | 1.69 | 36.6 | 1.39 | 4,000 | 30 | 0 | 0 |
| 5 | 8(e) | WADC-6 | Radius on nose | 4.62 | 1.794 | 2.58 | .405 | .496 | 1.62 | 35.1 | 1.39 | 4,000 | 30 | 0 | 0 |
| 6 | 8(f) | WADC-6 | Radius on nose | 4.62 | 1.794 | 2.58 | .413 | .496 | 1.62 | 35.1 | 1.39 | 4,000 | 20 | 0 | 0 |
| 7 | 8(g) | WADC-8 | Truncated cone | 4.62 | 1.794 | 2.58 | .409 | .523 | 1.62 | 35.1 | 1.39 | 4,000 | 30 | 0 | 0 |
| 8 | 8(h) | WADC-9 | Stabilizing fences | 4.62 | 1.794 | 2.58 | .402 | .508 | 1.62 | 35.1 | 1.39 | 4,000 | 30 | 0 | 0 |
| 9 | 8(i) | WADC-2 | No plate | 4.62 | 1.794 | 2.58 | 1.132 | 1.245 | 1.60 | 34.6 | 1.98 | 29,000 | 30 | 0 | 0 |
| 10 | 8(j) | WADC-2 | No plate | 4.62 | 1.794 | 2.58 | 1.136 | 1.245 | 1.61 | 34.9 | 1.98 | 29,000 | 30 | 0 | 0 |
| 11 | 8(k) and (l) | WADC-4 | WADC-1 plus plate | 4.62 | 1.794 | 2.58 | 1.154 | 1.300 | 1.61 | 35.0 | 1.98 | 29,000 | 30 | 3 | 0 |
| 12 | 8(m) | WADC-5 | WADC-1 plus plate | 4.62 | 1.794 | 2.58 | .485 | .740 | 1.56 | 33.8 | .8 | 4,000 | 30 | 0 | 0 |
| 13 | 8(n) | WADC-7 | Radius on nose | 4.62 | 1.794 | 2.58 | .485 | .740 | 1.61 | 35.0 | .8 | 4,000 | 30 | 0 | 0 |
| 14 | 9(a) | FC-1 | No plate | 3.95 | 1.480 | 2.71 | .384 | .451 | 1.60 | 40.0 | 1.39 | 4,000 | 30 | 0 | 0 |
| 15 | 9(b) | FC-2 | 1 small plate | 3.95 | 1.480 | 2.71 | .406 | .451 | 1.58 | 39.5 | 1.39 | 4,000 | 30 | 0 | 0 |
| 16 | 9(c) | FC-3 | 1 large plate | 3.95 | 1.480 | 2.71 | 1.219 | 1.264 | 1.68 | 42.0 | 1.98 | 35,000 | 30 | 0 | 0 |
| 17 | 9(d) | FC-4 | 2 plates | 3.95 | 1.480 | 2.71 | 1.264 | 1.494 | 1.58 | 39.5 | 1.98 | 35,000 | 30 | 0 | 0 |
| 18 | 10(a) | C-1 | | 2.78 | 1.794 | 1.55 | .370 | .340 | 1.07 | 38.5 | 1.39 | 4,000 | 30 | 0 | 0 |
| 19 | 10(b) | C-5 | | 3.87 | 1.525 | 2.54 | .246 | .255 | 1.36 | 35.1 | 1.39 | 4,000 | 30 | 0 | 0 |
| 20 | 10(c) | C-6 | | 3.87 | 1.525 | 2.54 | .238 | .242 | 1.75 | 45.0 | 1.39 | 4,000 | 30 | 0 | 0 |
| 21 | 10(d) | C-7 | | 4.63 | 1.525 | 3.04 | .247 | .263 | 1.62 | 35.0 | 1.39 | 4,000 | 30 | 0 | 0 |
| 22 | 10(e) | C-8 | | 4.63 | 1.525 | 3.04 | .255 | .292 | 2.09 | 45.1 | 1.39 | 4,000 | 30 | 0 | 0 |
| 23 | 10(f) | C-3 | | 3.64 | 1.794 | 2.03 | .385 | .526 | 1.28 | 35.2 | 1.39 | 4,000 | 30 | 0 | 0 |
| 24 | 10(g) | C-4 | | 3.64 | 1.794 | 2.03 | 1.151 | 1.127 | 1.61 | 44.2 | 1.39 | 35,000 | 30 | 0 | 0 |
| 25 | 10(h) | C-4 | | 3.64 | 1.794 | 2.03 | 1.151 | 1.127 | 1.61 | 44.2 | 1.98 | 35,000 | 30 | 0 | 0 |

1.79 diam

1.37 diam

1.79 diam

Station 0    1.63    3.66  4.62
                2.07        4.10

Stores WADC-1 and WADC-2

.0625
 .375

Stores WADC-3, WADC-4, and WADC-5

.112 radius

Stores WADC-6 and WADC-7

Store WADC-8

3.41

Store WADC-9

L-95758

Figure 1.- Drawings and photographs of WADC stores.

1.48 diam    1.79 diam

Station 0          3.05  3.95
                    3.71        Store FC-1

1.48 diam

-.24               Store FC-2

1.79 diam

-.24               Store FC-3

1.22 diam
1.79 diam

-.65
-.24               Store FC-4

L-95759
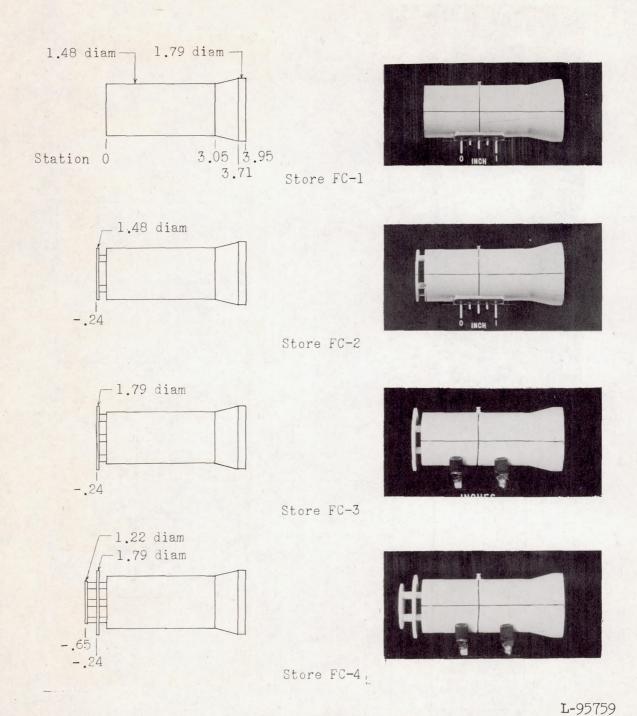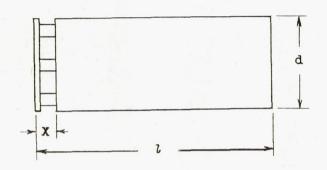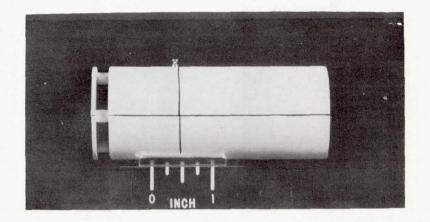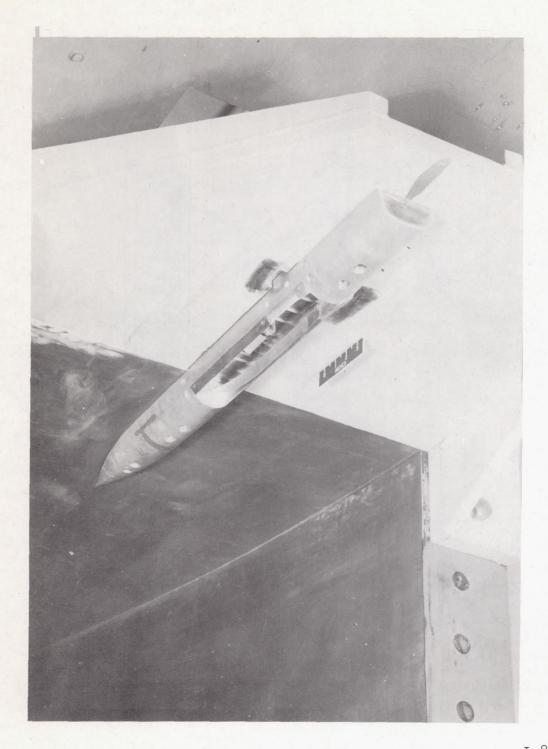
Figure 2.- Drawings and photographs of flared-cylinder stores.
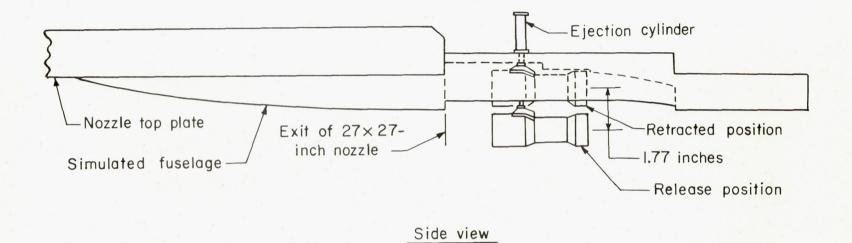
| Store | X | $l$ | d | $l/d$ |
|-------|-----|------|-------|------|
| C-1 | .33 | 2.78 | 1.794 | 1.55 |
| C-3<br>C-4 | .33 | 3.64 | 1.794 | 2.03 |
| C-5<br>C-6 | .29 | 3.87 | 1.525 | 2.54 |
| C-7<br>C-8 | .29 | 4.63 | 1.525 | 3.04 |

L-95760

Figure 3.- Drawing and typical photograph of cylindrical stores.

L-86079

Figure 4.- Photograph showing the simulated fuselage mounted in the
preflight jet of the Langley Pilotless Aircraft Research Station
at Wallops Island, Va.

Ejection cylinder

Nozzle top plate

Simulated fuselage

Exit of 27×27-
inch nozzle

Retracted position

1.77 inches

Release position

Side view

Bottom view
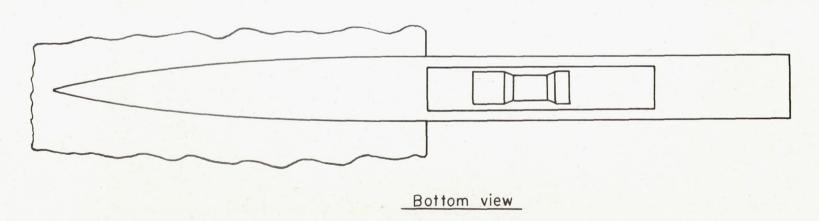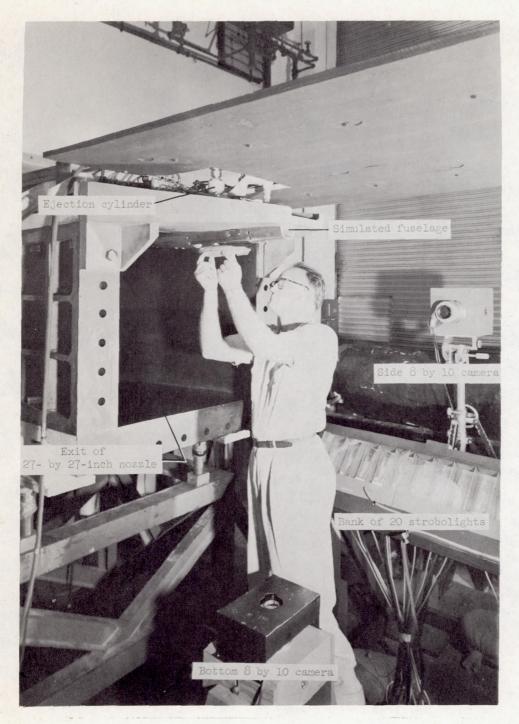
Figure 5.- Sketch of typical store in retracted and in release positions.

Figure 6.- Arrangement of equipment in preflight jet (open jet).

L-86179.2

L-95761
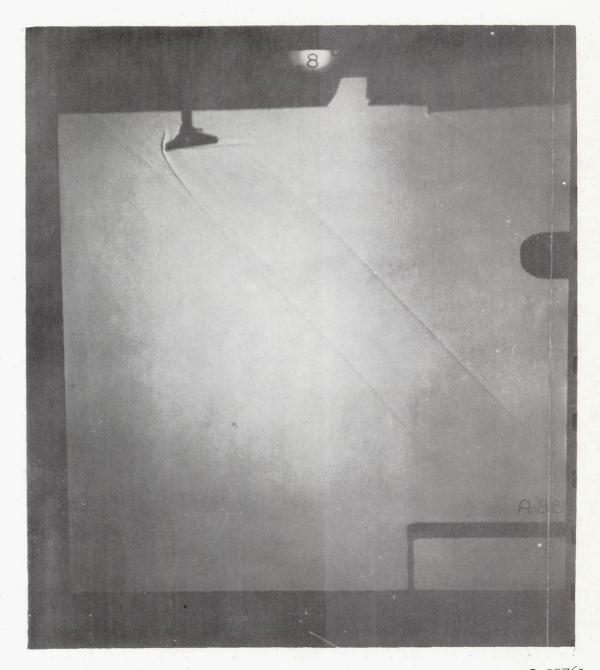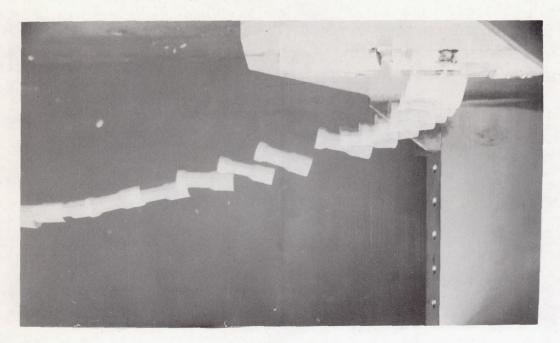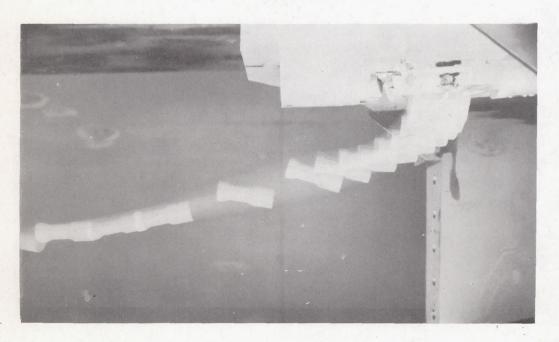
Figure 7.- Shadowgraph of flow field at $M = 1.39$ in the close vicinity of the bomb bay showing the ejector ($i_0 = -6^\circ$) in extended position.
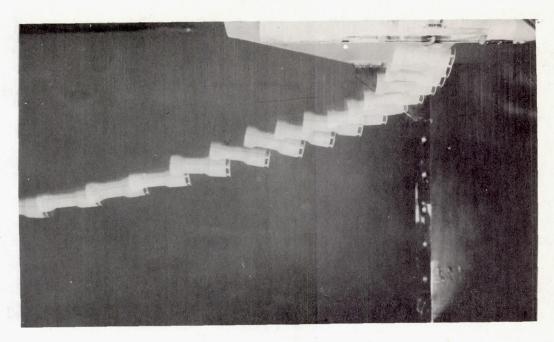
(a) Test 1; store WADC-1.
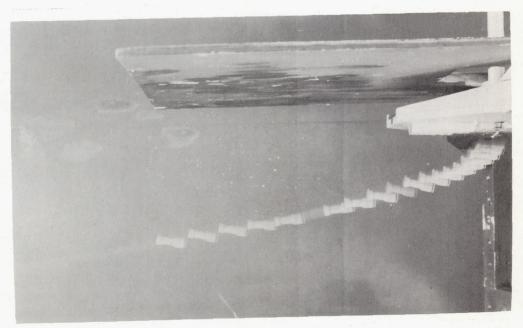


(b) Test 2; store WADC-1.                                     L-95762

Figure 8.- Strobolight pictures showing release of WADC stores.
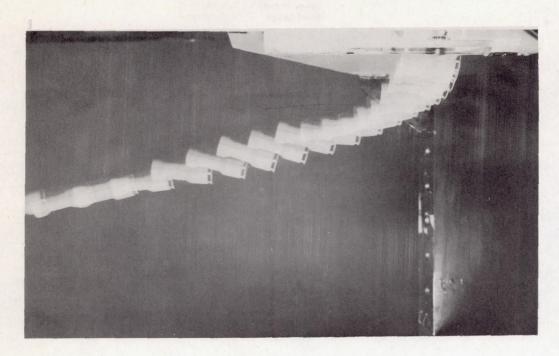
(c) Test 3; store WADC-3.
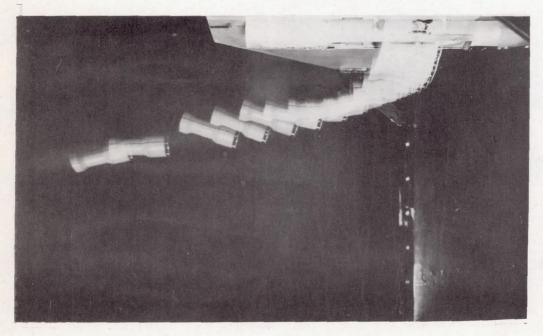


(d) Test 4; store WADC-3.

L-95763

Figure 8.- Continued.
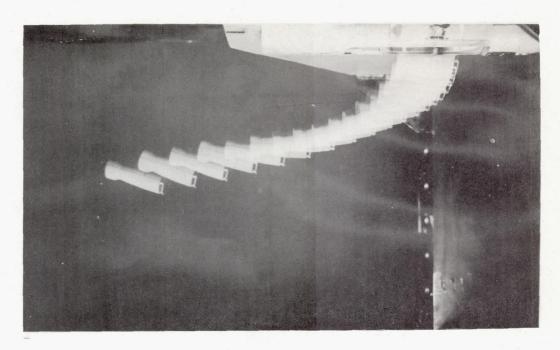
(e) Test 5; store WADC-6.
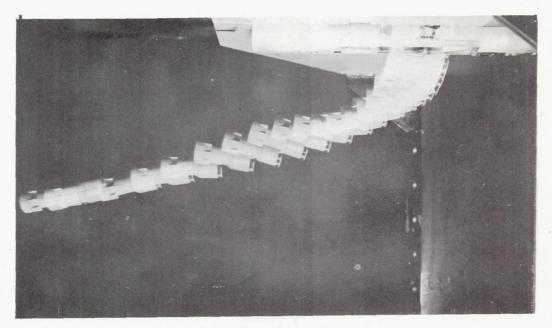


L-95764

(f) Test 6; store WADC-6.

Figure 8.- Continued.
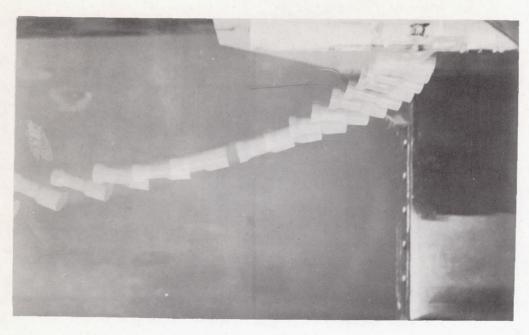
(g) Test 7; store WADC-8.



L-95765
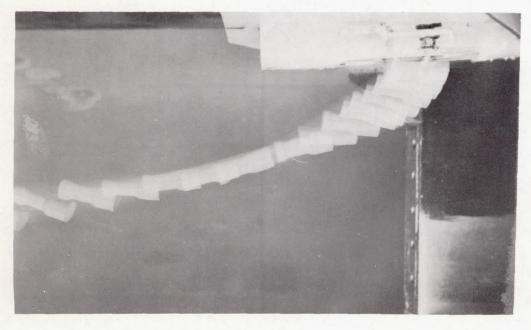
(h) Test 8; store WADC-9.

Figure 8.- Continued.
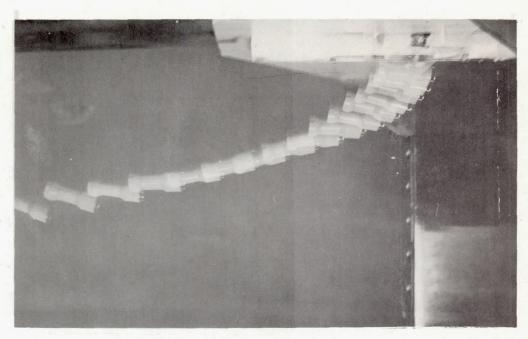
(i) Test 9; store WADC-2.
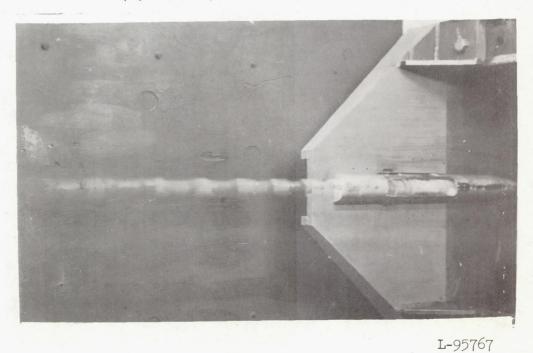


(j) Test 10; store WADC-2.

L-95766

Figure 8.- Continued.
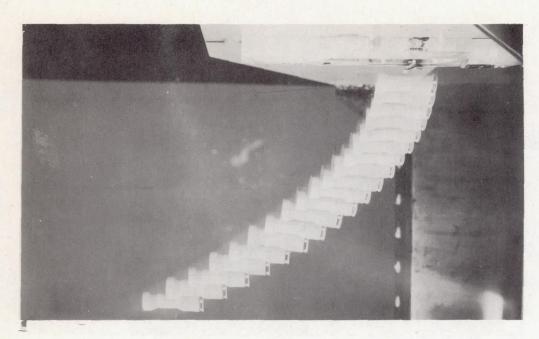
(k) Test 11; side view; store WADC-4.



L-95767
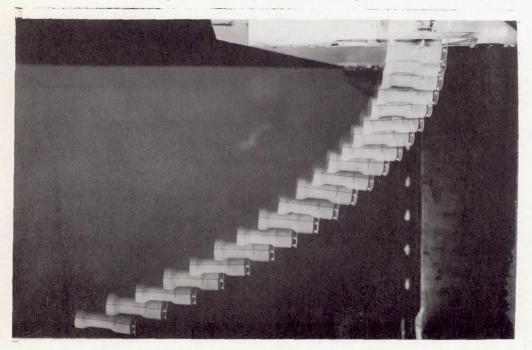
(l) Test 11; bottom view; store WADC-4.

Figure 8.- Continued.

(m) Test 12; store WADC-5.



L-95768
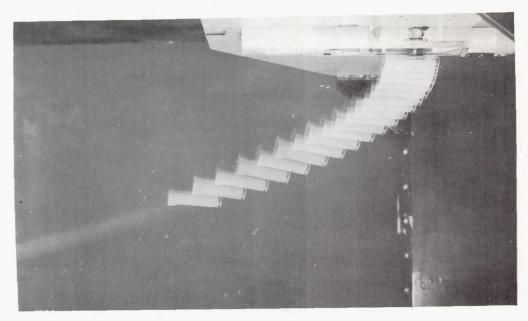
(n) Test 13; store WADC-7.

Figure 8.- Concluded.

(a) Test 14; store FC-1.



L-95769

(b) Test 15; store FC-2.
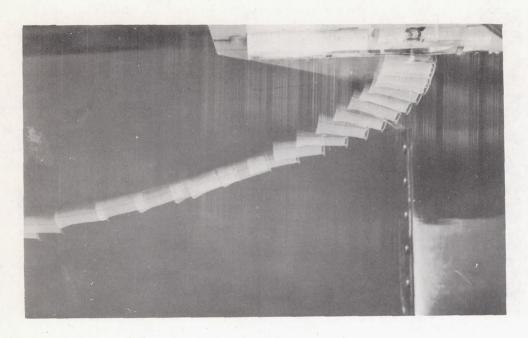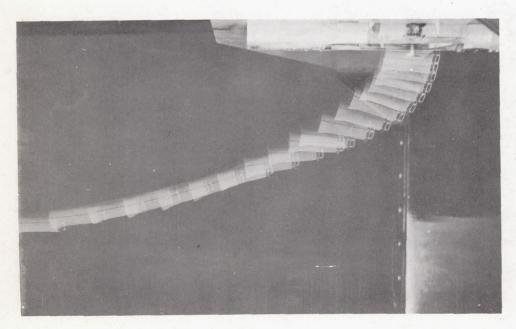
Figure 9.- Strobolight pictures showing release of flared-cylinder stores.

(c) Test 16; store FC-3.



L-95770
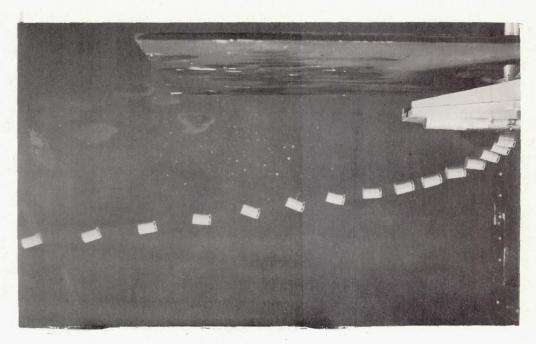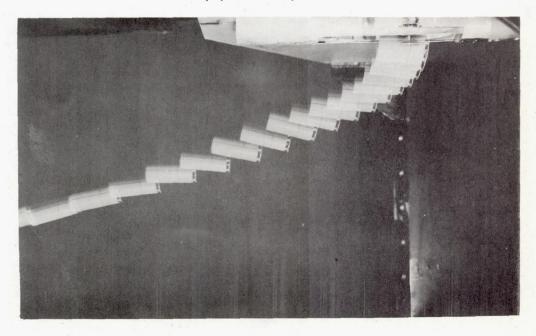
(d) Test 17; store FC-4.

Figure 9.- Concluded.
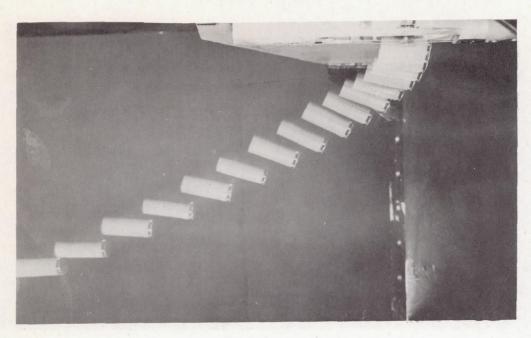
(a) Test 18; store C-1.
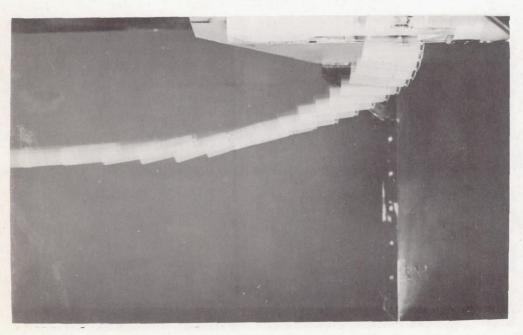


(b) Test 19; store C-5.

L-95771

Figure 10.- Strobolight pictures showing release of cylindrical stores.
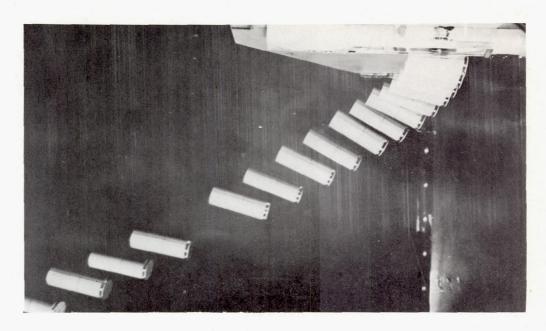
(c) Test 20; store C-6.



(d) Test 21; store C-7.                    L-95772

Figure 10.- Continued.
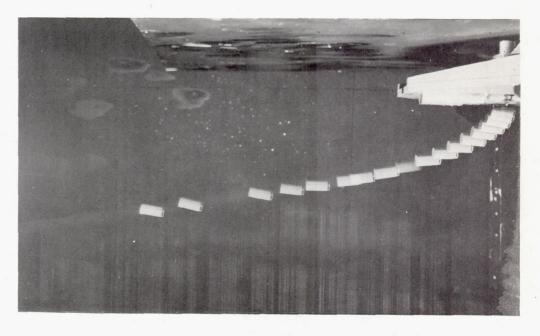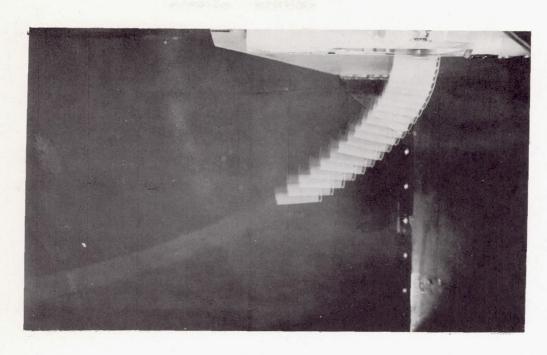
(e) Test 22; store C-8.
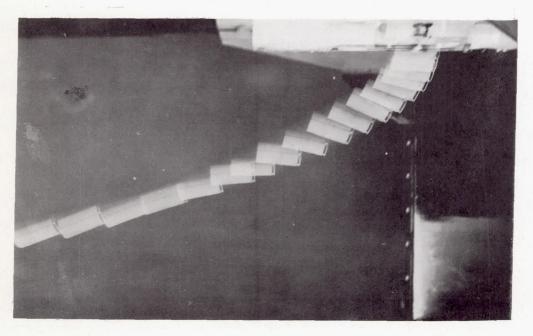


(f) Test 23; store C-3.                    L-95773

Figure 10.- Continued.
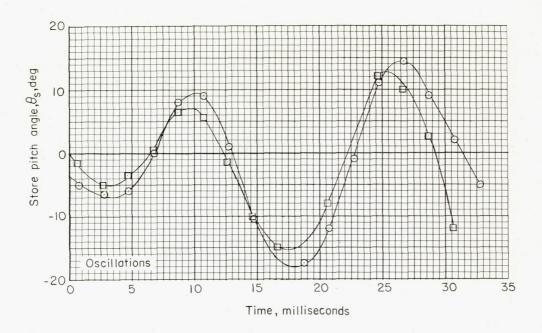
(g) Test 24; store C-4.
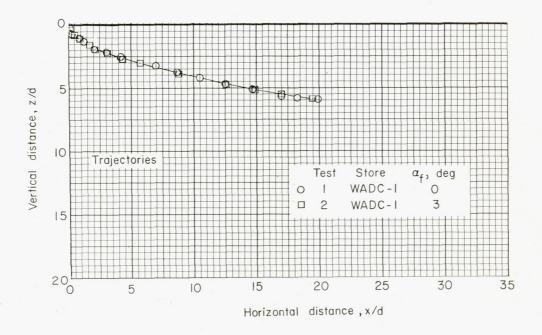


(h) Test 25; store C-4.                    L-95774

Figure 10.- Concluded.
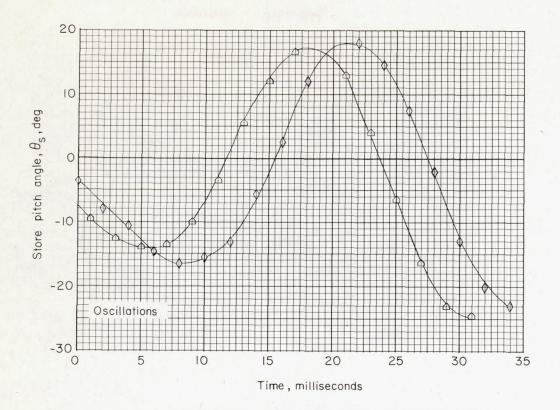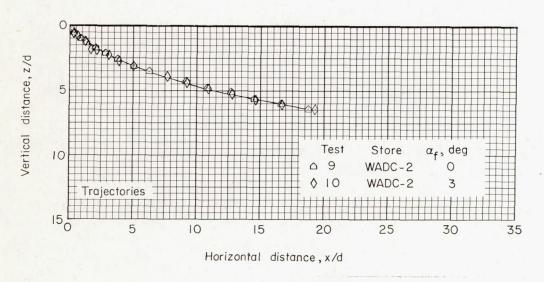
(a)  M = 1.39;  $h_p$ = 3,400 feet.
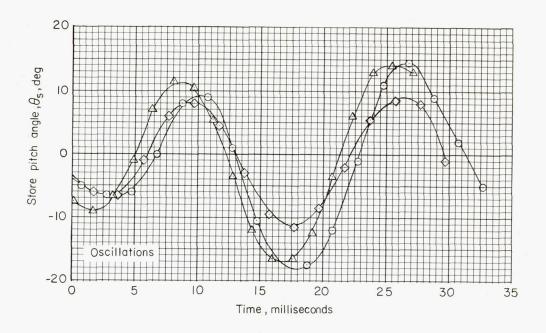
Figure 11.- Comparison of some WADC store releases to show effect of fuselage angle of attack.
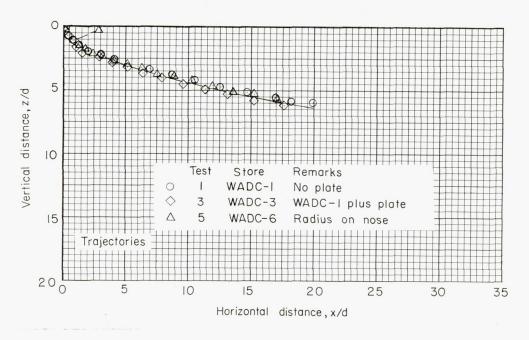
(b)  M = 1.98; $h_p$ = 29,000 feet.
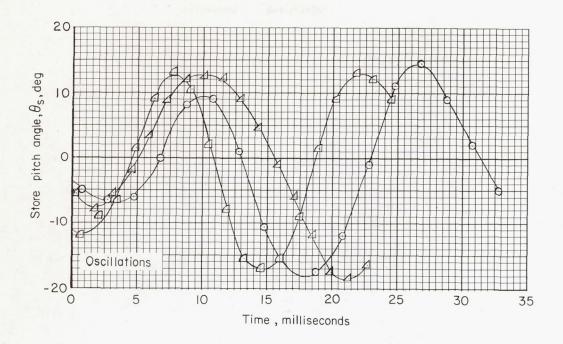
Figure 11.- Concluded.
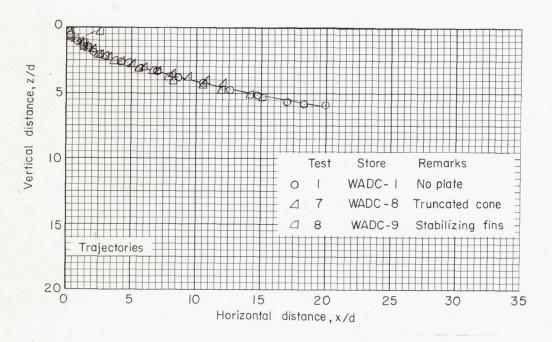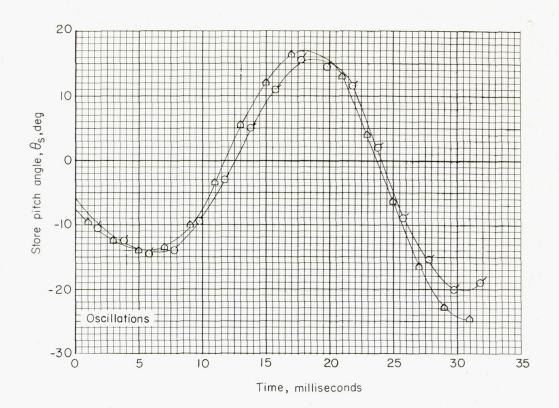
(a) Comparisons at M = 1.39.

Figure 12.- Comparison of some WADC store releases to show the effect of some external changes.

(b) Comparisons at M = 1.39 - continued.

Figure 12.- Continued.

(c)  M = 1.98; $h_p$ = 29,000 feet.
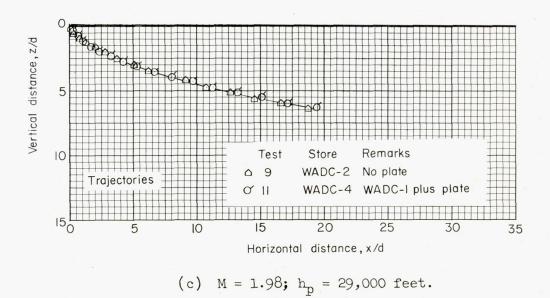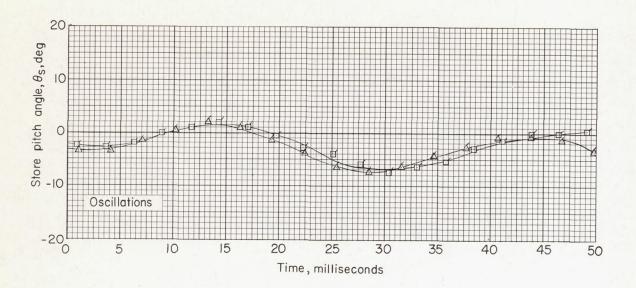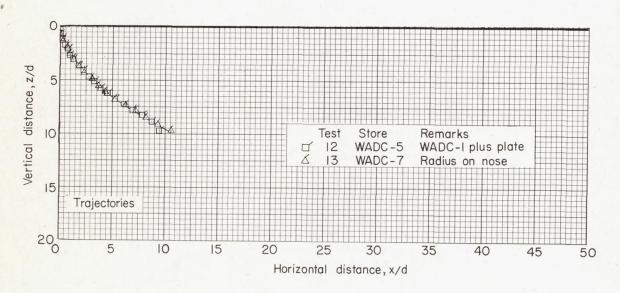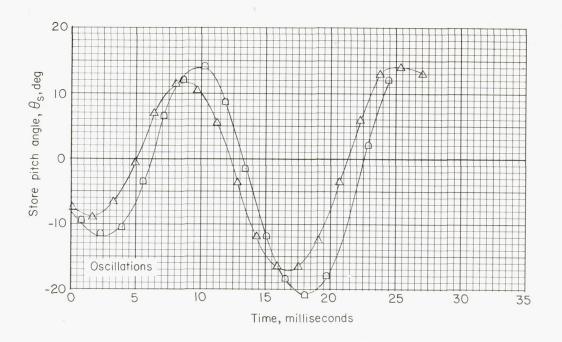
Figure 12.- Continued.

(d)  M = 0.8; $h_p$ = 4,000 feet.

Figure 12.- Concluded.
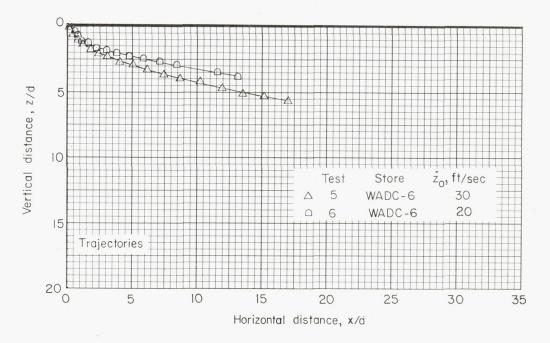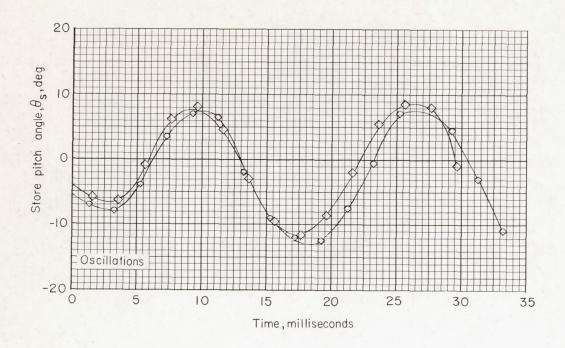
Figure 13.- Comparison of two WADC store releases to show effect of initial ejection velocity.  M = 1.39; $h_p$ = 4,000 feet.
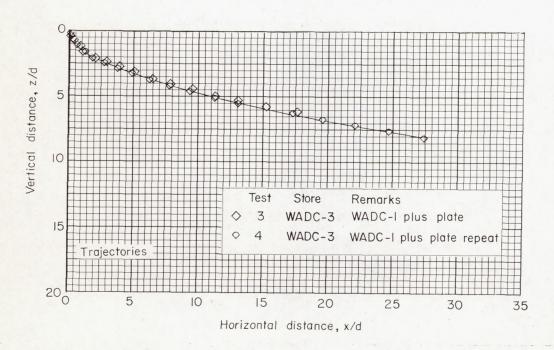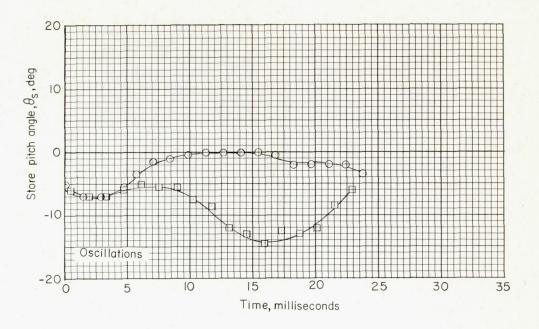
Figure 14.- Comparison of two WADC store releases to show repeatibility.
M = 1.39; $h_p$ = 4,000 feet.

(a)  M = 1.39; $h_p$ = 4,000 feet.
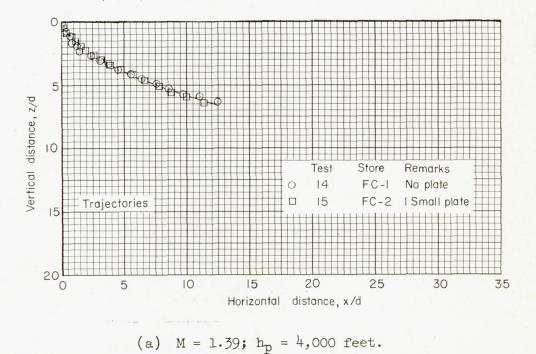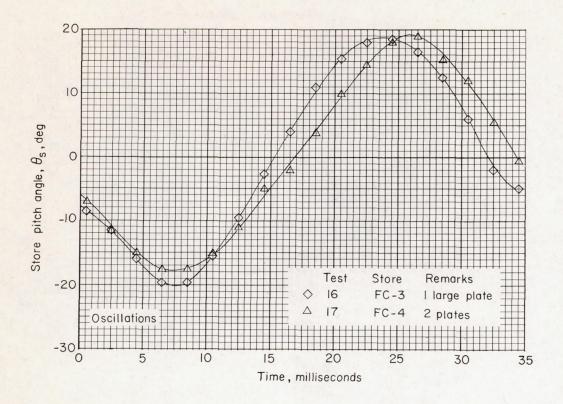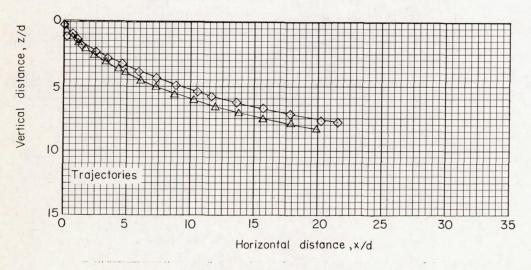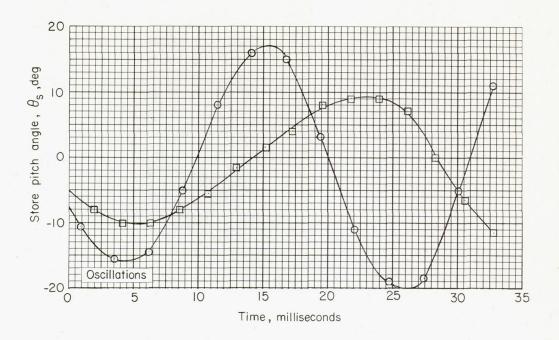
Figure 15.- Comparison of some flared-cylinder store releases to show effect of some plate additions.

(b)  M = 1.98; $h_p$ = 35,000 feet.

Figure 15.- Concluded.
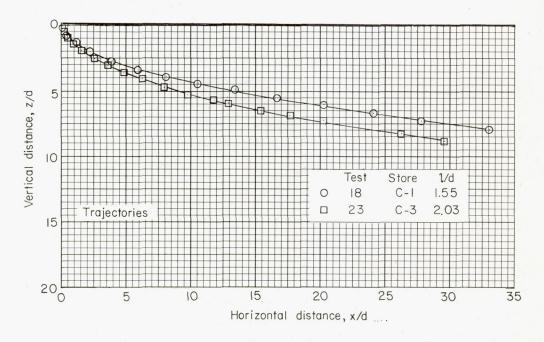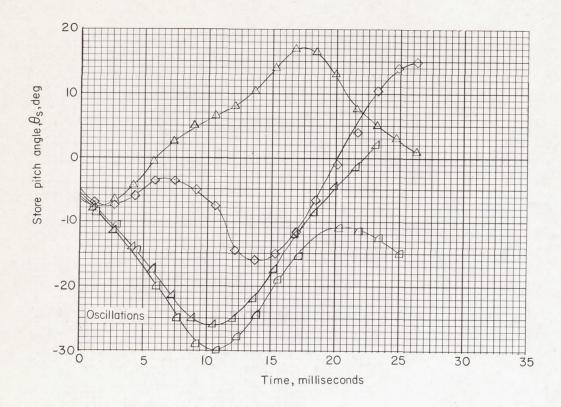
Figure 16.- Comparison of two cylindrical store releases to show effect of fineness ratio.  M = 1.39; $h_p$ = 4,000 feet.
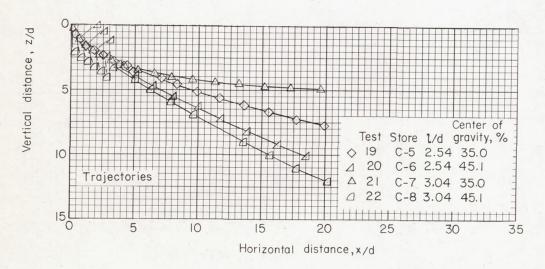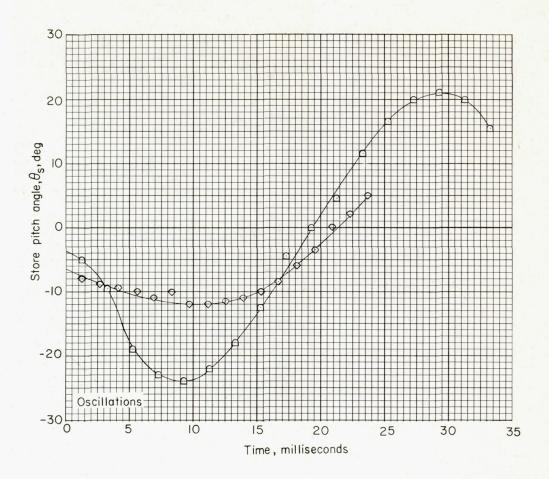
Figure 17.- Comparison of four cylindrical store releases to show effect of fineness ratio and effect of center-of-gravity position. M = 1.39; $h_p$ = 4,000 feet.
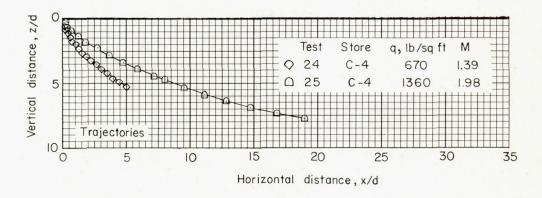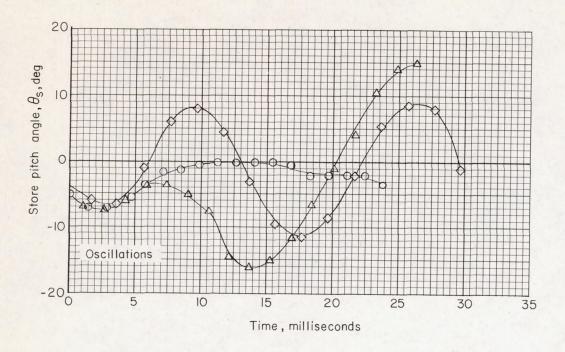
Figure 18.- Comparison of two cylindrical store releases to show
effect of a combination change in Mach number and dynamic
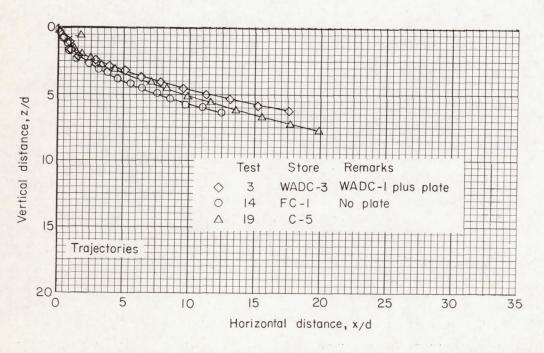pressure.  $h_p$ = 35,000 feet.

Figure 19.- Comparison of the best store release from each of the three types tested.